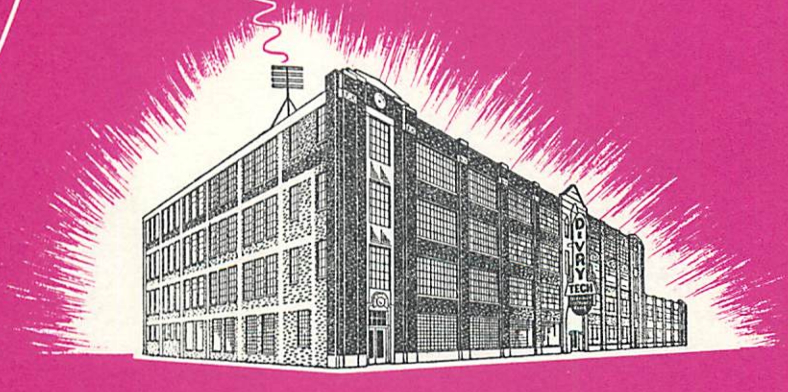
COLOR TV RECEIVER PICTURE TUBES

Lesson T4E-7A



DeVRY Technical Institute
4141 W. Belmont Ave., Chicago 41, Illinois
Formerly DeFOREST'S TRAINING, INC.

T4E-7A

COLOR TV RECEIVER PICTURE TUBES

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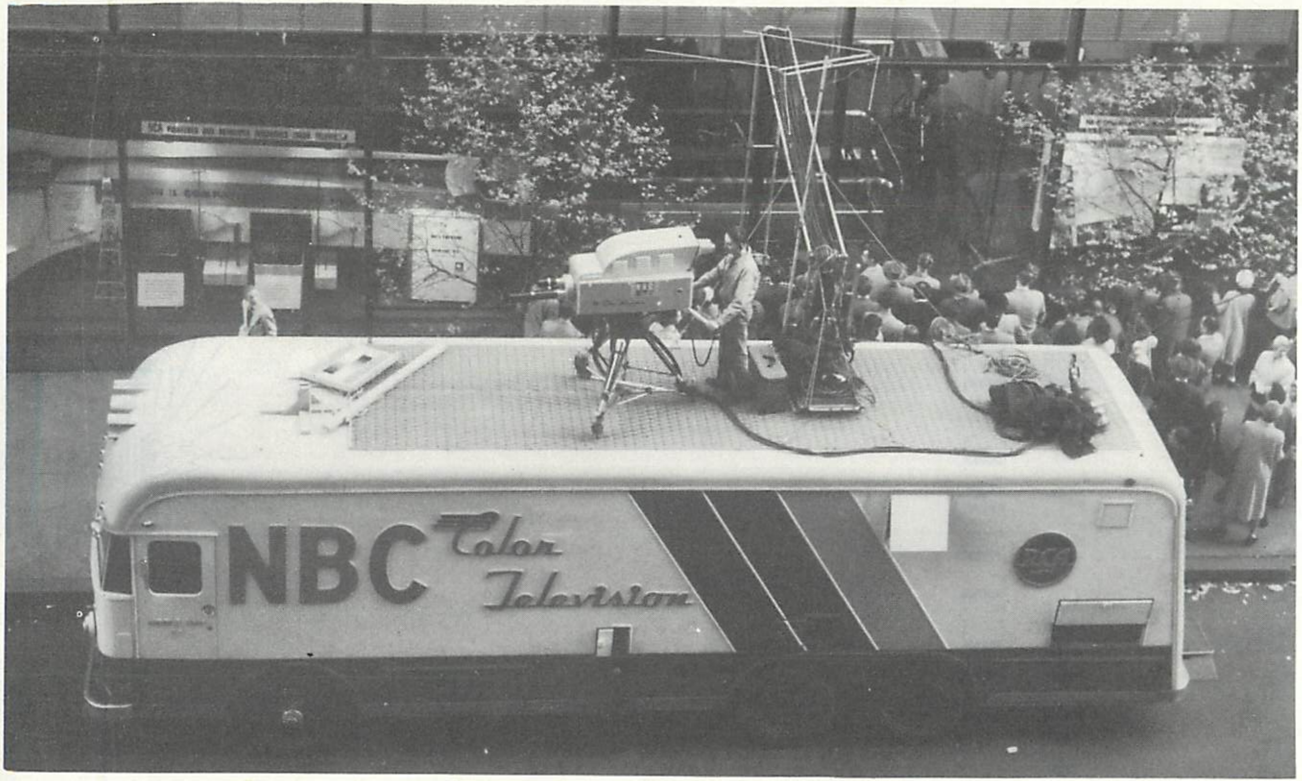

A remote color television unit requires a rather large truck to accommodate the necessary equipment.

Courtesy Radio Corporation of America

COLOR TV RECEIVER PICTURE TUBES

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David Sarnoff may well be called the champion of television. He has the faith, stout heart, unyielding spirit and indomitable will to bring television into every home. As a veteran in the field he has seen radio and electronic research hurdle many barriers: He knows beyond doubt that television will do the same; there's no stopping it. To him, it is not the facts of yesterday but the progress of tomorrow that determines its destiny. Mr. Sarnoff predicts, "The advances of the next fifty years will make those of the last fifty pale into insignificance."

—Anon

COLOR TV RECEIVER PICTURE TUBES

Ever since the late 1920's, inventors and scientists have been searching for ways to improve the reproduction of a color image on a television receiver. During that time, and through the 1930's, the mechanical scanning disk method was the most successful of all systems. Finally, in about 1940, the field-sequential color television system using a rotating color disk came into being. This method was pioneered by the Columbia Broadcasting System and it appeared for a while that it was the system that would eventually be used.

FIELD SEQUENTIAL TRANSMISSION

In its simplest form the Columbia Broadcasting System of color television can be considered as a black-and-white system to which rotating color discs have been added. As indicated in Figure 1A, a rotating color disc containing green, blue, and red filters is mounted in front of the camera tube. During the time the green portion of the disc is between the camera tube and the subject, only the portions of the subject that are green cause response in the tube and the transmitter circuits. The corresponding video signal is picked up by the receiving antenna and the partial image is formed on the picture tube.

As shown in Figure 1B, a rotating color disc is mounted in front of the picture tube screen. Moving in exact synchronism with the color disc at the transmitter, the green filter will cause the observer to see a green image.

When the blue portion of the transmitter disc moves into position a fraction of a second later, the blue portions of the subject are transmitted and appear on the receiver picture tube. Here, the blue filter has moved up in front of the picture tube and the observer sees the blue portions of the image. However, due to persistence of vision, he still sees the previous green portion of the image also. Then with the transmission of the red portions, the image is complete. Visual response to the two previous colors is still effective, and the eye combines the green, blue, and red images with the result that the subject appears in color.

How colors other than the three which make up the disc are reproduced can be understood by a specific case. For example, assume the subject's hat is purple. Since purple is made up of both red and blue, light from the hat passes through both the red and blue filters of the transmitter disc, and produces output signals from the camera tube. On the picture tube screen, the received signals produce an image of the hat during the time that both the red and blue filters of the receiver disc are in front of the tube. The persistence of vision causes the red and blue images to blend in the observer's eye, thus giving the sensation of purple.

A similar action occurs for all other colors. Each is made up of varying amounts of the three primary colors.

It is important that the mosaic of the camera be completely discharged at the completion of each color field. If it is not, colors are combined to give a very undesirable and unnatural appearance at the receiver. Too much afterglow on the part of the picture tube causes a similar effect. Since the mosaic must be completely discharged at the completion of each field, there is a tendency for flicker. Therefore the colored images should be transmitted at a relatively high field rate.

This system has been in the process of development for a number of years and has gone through a great many modifications. The equipment demonstrating the system in 1940 used 343 lines per frame and 120 fields per second. Operation was on one of the standard six megacycle channels. The resultant lack of definition and the poor reproduction of some shades led to some postwar developments with encouraging results. In 1946, advantage was taken of a greater bandwidth to improve the quality of the picture. Accordingly, the six megacycle bandwidth was discarded and 16 mc substituted. Also, there was a change to 525 lines and 144 fields, resulting in greater detail and less flicker.

Color television reception can be obtained by a special converter which is attached to a black and white TV receiver.

Courtesy Color Converter, Inc.

Later the bandwidth was reduced to twelve megacycles and the number of lines to 441. Finally, the bandwidth was reduced to 4.5 mc, and the number of lines changed to 405 with 144 fields per second. The number of picture elements is appreciably less than in the standard black-and-white pictures, but the addition of color compensates in part for the lack of detail. The reduction of the bandwidth was a very important advancement since it makes possible the use of the standard black-and-white channels.

Figure 2 shows the **color switching** sequence employed in the CBS system. Here, as in the black-and-white system, the term field pertains to the scanning of one set of odd or even lines, during which time a single primary color filter is in front of the camera lens. That is, the rotation speed of the color disc is such that each successive filter covers the lens for 1/144th of a second, during which interval the camera tube beam completes 202½ horizontal sweeps, or one FIELD. During the next field period, another filter is in front of the camera, and the other set of lines (even or odd) is scanned.

Thus, in an interval of 2x1/144, or 1/72 of a second, two complete fields are scanned, one even and one odd, for a total of 405 horizontal lines or sweeps of the beam. The scanning of any pair of successive fields is called a FRAME, and two colors are scanned during each frame period. These definitions of field and frame apply, regardless of the color of the filter in front of the camera at any instant.

Each group of 3 successive fields, including one scanning in each color, occupies a time interval of 3 x 1/144, or 1/48th of a second, and is called a COLOR FRAME. As in the case of the frame, a color frame may begin with either an odd or even-line field, and with any one of the three colors. In a like manner, any two successive color frames constitute a COLOR PICTURE. As indicated, each color picture occupies 1/24th of a second, and includes the entire cycle of operation during which both the odd and even lines are scanned in all three colors. Thus, the system provides 24 color pictures per second, with the fields interlaced 2-to-1 to reduce flicker.

The following important values are listed to provide a direct comparison of the standard black-and-white with the CBS color television.

	Standard Black and White	CBS Color
Lines per frame	525	405
Fields (per sec.)	60	144
Frames (per sec.) 2 fields	30	72
Color frames 3 fields	......	48
Color Pictures 6 fields	......	24
Horizontal Deflection frequency	15,750 cps	29,160 cps
Vertical Deflection frequency	60 cps	144 cps

Color Disc Speed:

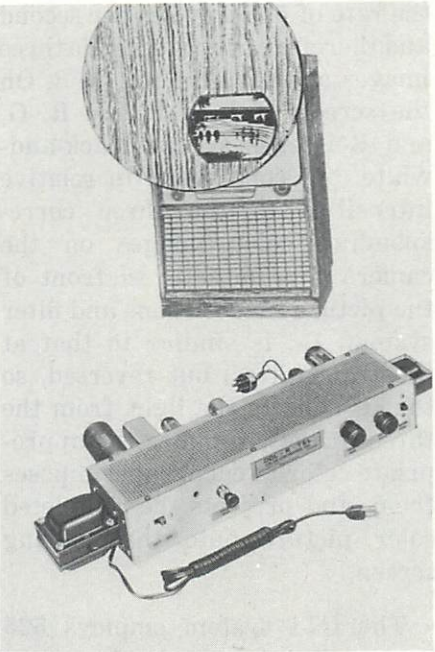
3 filters — as in Figure 1 —	2880 RPM
6 filters	*1440 RPM*
12 filters	720 RPM

For a large direct view receiver screen, the rotating filter disc must have rather cumbersome proportions if the mechanical components of the CBS system is retained, because the disc must have at least twice the diameter of the picture tube. However, the **field sequential system** of color switching may be achieved by optical and electronic means in a manner similar to that of some "all-electronic" systems which have been developed.

Due to the fact that this is a simple system, especially when used in closed circuits, it is very popular for industrial color television. However, it isn't the only one. Other systems have been devised, one of which is the FCC adopted standard for broadcast television. So let's consider the important features in these other systems.

LINE SEQUENTIAL TRANSMISSION

Employing color switching at the standard black-and-white line scanning rate of 15,750 per second, a second type of sequential system has been developed by Color Television Incorporated (CTI). Illustrated in Figure 3, this system employs pickup and reproducing tubes of the same type as used in black-and-white television. For the pickup action, Figure 3, the trichromatic lens and filter system, L_1, projects three images of different color onto the mosaic of the iconoscope, I. Indicated as R, G, and B, the respective red, green, and blue images are grouped side by side as shown, but do not overlap.



The color converter unit at the bottom of the picture is usually installed so that the controls are accessible to the customer.

Courtesy Color Converter, Inc.

Sweeping horizontally at the rate of 5,250 cycles per second, the iconoscope scanning beam traces over all three images as though they were a single picture. However, with this arrangement, the beam travels across any one image in one-third the time required to move across all *three.*

Therefore, for each complete horizontal sweep, the samples of color information are transmitted as a ⅓ line of red, a ⅓ line of green and a ⅓ line of blue, in sequence.

At the receiver, the picture tube beam is deflected horizontally at the rate of 5,250 cycles per second and therefore reproduces the three images as shown in Figure 3. On the screen of tube P, the R, G, and B images are all black-and-white, but correspond in relative intensities to the three corresponding color images on the camera tube mosaic. In front of the picture tube the lens and filter system, L_2, is similar to that at the transmitter, but reversed, so that it collects the light from the three images, supplies the appropriate color to each, superimposes them, and projects the completed color picture onto the viewing screen.

The CTI system employs 525 lines per picture as in the black-and-white system. However, as the horizontal sweep rate is only 5,250 per second, the arrangement produced $5{,}250 \div 525 = 10$ color pictures per second, or one-third the number of frames provided by the black-and-white system.

COLOR PHOSPHORS

The systems described worked on the principle of producing white light and passing it through a color filter. Most luminescent materials naturally produce colors other than white and the so-called "white" phosphors used in TV receiver picture tubes are actually mixtures of two or more phosphors, the combined output of which is white light. In view of this fact, the use of such white phosphors, with a color filter is very inefficient since the energy of the electron beam must divide itself among two or three phosphors with only a portion of the light passing through the filter.

The most efficient use of the energy contained in the electron beam is to eliminate filters by choosing phosphors that will emit the proper color light. Accordingly, experiments were conducted by RCA and other organizations which resulted in phosphors that would emit red, green, and blue light with a fairly high degree of efficiency. The most difficulty was encountered with the development of a suitable red phosphor as the various materials available were much more inefficient than those used for producing green and blue light. In fact, even though considerable improvement has been made since the beginning of these experiments, the red emitting phosphors are still the most inefficient and compensating methods must be taken to equalize the light output.

LINE SCREEN COLOR KINESCOPE

One of the earliest developments among color kinescopes for receiver use was the line-screen system shown in Figure 4. In this color kinescope, a horizontal phosphor strip for each primary color is placed sequentially on the screen. That is, there is a red strip, a green strip, a blue strip, a red strip, a green strip, a blue strip, etc. To reproduce a picture that contains about 500 active scanning lines, the total number of strips would have to be about 1500 or about 500 strips of each color. Line screens with this method require PHOSPHOR LINES which are smaller than one third of the distance between scanning lines.

To prevent the scanning beam from striking more than one color phosphor at a time, the beam must be focused to a very small spot and the scanning system must be extremely accurate. Consequently, rather complex automatic control and registry circuits had to be devised to accomplish the desired results.

ADJACENT IMAGE COLOR KINESCOPE

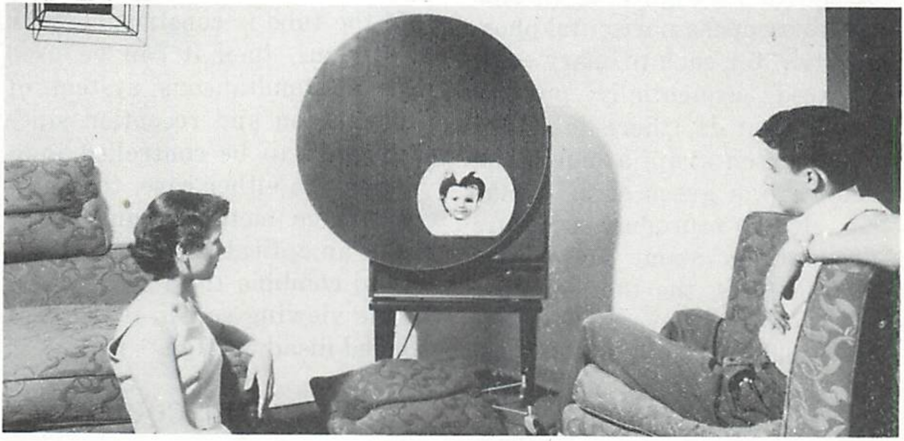
Not far behind the line screen kinescope came experiments on the ADJACENT IMAGE SYSTEM. Very similar to the CTI system of Figure 3, this system required that three images be reproduced side by side as shown in Figure 5. If only one gun is used (as illustrated), the method is restricted to either line sequential or field sequential presentation.

If the tube is constructed with three guns, then it can be used with a simultaneous system of transmission and reception since each gun can be controlled individually. In either case, the adjacent image method requires the use of an optical registration system to combine the three images on the viewing screen which is a decided disadvantage.

CHROMOSCOPE

Another color-tube, devised by Dr. Bronwell of Northwestern University, is called the chromoscope. Closely spaced but insulated from each other, four semitransparent screens are arranged in layers behind the tube face. Screens R, B, and G are coated with phosphors which make one emit red, one blue, and the other green light. The fourth screen, P, does not add color, but is maintained at a constant potential to aid in focusing the beam.

When struck by beam electrons, each color will fluoresce only if a positive potential is applied. Therefore, the sampling or switching control voltage is employed in such a way as to apply positive impulses to the three color screens in sequence at the desired sampling rate, while the video signal is applied to the grid of the electron gun. Produced on the semi-transparent screens, the three color images appear superimposed to the observer who therefore, receives the impression of a complete color picture as though it existed on a single screen.



This is the way the final installation appears. Notice the large disc necessary to reproduce the picture.

Courtesy Color Converter, Inc.

BAIRD TUBE

A picture tube developed by the late John Logie Baird, of England, uses a three gun tube and a special screen of green, red, and blue phosphors. The screen consists of a thin sheet of transparent mica, ridged on one side and flat on the other. One side of each ridge is coated with blue-emitting phosphor and the other side with green-emitting phosphor, while the flat side of the screen is coated with red-emitting phosphor. Each electron gun is placed at the proper angle so that its beam will strike only one phosphor. Because the screen is transparent all three color images can be seen from either side and thus appear superimposed to the observer.

TRICHROMOSCOPE

One unit developed by Allen B. DuMont Laboratories has the inside of the picture tube face molded into 300,000 small 3-sided pyramids. All pyramid sides facing in one direction are coated with a phosphor that glows red. All sides facing in a second direction are coated with a phosphor which glows blue and the remaining sides are coated with a phosphor which glows green. Three electron guns are mounted so that the beam from each bombards a different colored side of the pyramids. As the screen is transparent, a 3-color picture is seen by an observer looking at the tube face.

Both the Baird tube and the trichromoscope have the disadvantage in that each gun requires its own set of deflection coils. It is rather difficult to have the deflection voltages always matched when using separate coils.

SIMULTANEOUS TRANSMISSION

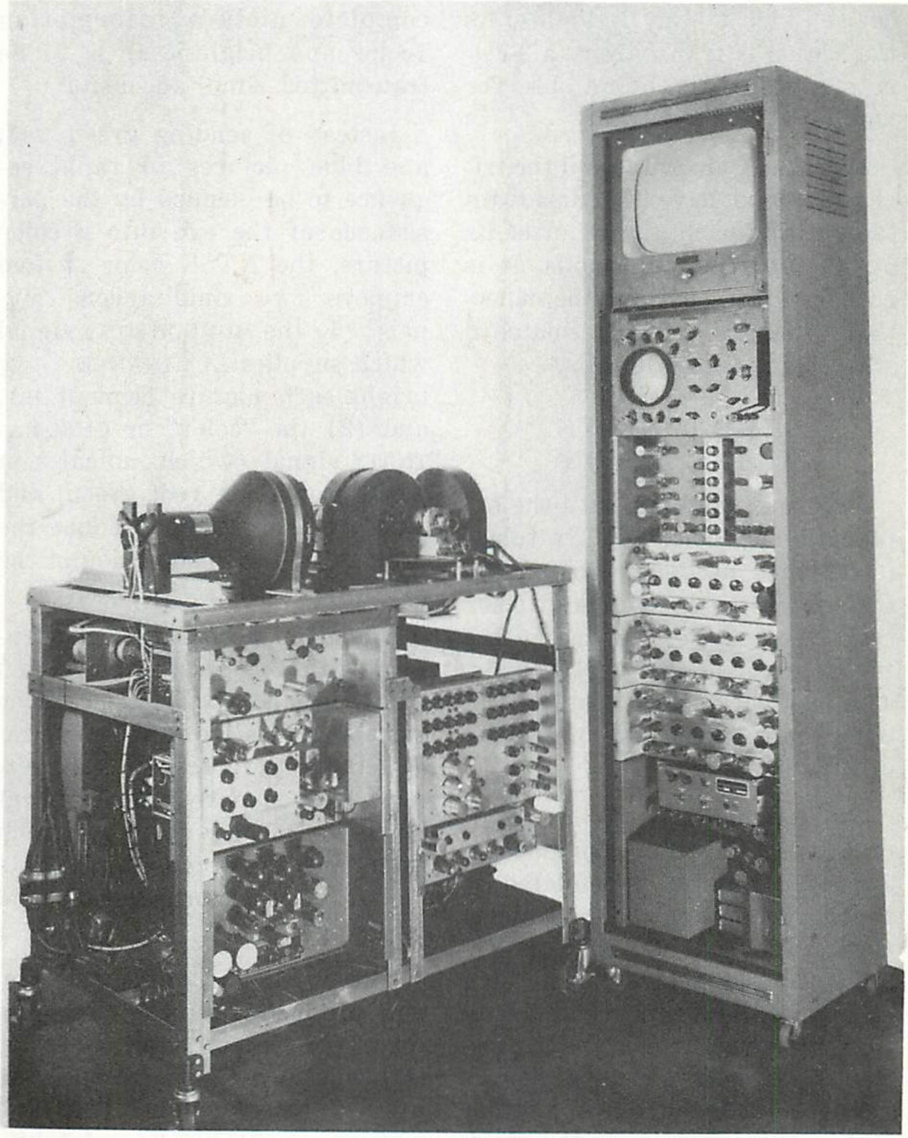
Before proceeding with the explanation of color picture tubes, it becomes necessary to explain the **simultaneous system** of color transmission. This is due to the fact that the method of transmission has had a considerable effect upon the requirements of the color picture tube.

On December 17, 1953, the Federal Communications Commission approved a system formulated by the National Television Systems Committee (NTSC) as the permanent technical transmission standards for commercial television broadcasting in the United States. Among these standards (full details are given in another lesson of this series) is the specification that the horizontal scanning frequency is to be 15,734.264 cycles per second and that the vertical scanning frequency is to be 59.94 cycles per second. Furthermore, it is specified that the complete picture information (color and brightness) is to be transmitted simultaneously.

Instead of sending green, red, and blue pictures in rapid sequence to be blended by the persistence of the eye into a color picture, the NTSC color system employs two simultaneous signals: (1) the MONOCHROME signal which supplies LUMINANCE (how bright each picture element is), and (2) the "color" or CHROMATICITY signal (which indicates in what proportion red, green, and blue are required to produce the proper hue for that portion of the picture).

The monochrome signal is identical with the present black and white broadcasts; precisely the same signal is transmitted as radiated by the present transmitters. Consequently, any present black and white receiver which intercepts these color broadcasts will produce a normal black and white picture.

This is called a compatible system producing 30 complete pictures per second, and all color transmissions can be received on present receivers in black and white and all black and white transmissions can be received on the color receivers. So complete is this feature that a black and white set owner has no way of knowing whether he is receiving a black and white or a NTSC color signal.



This is the simplified version of the CBS Chromocoder. It enables a standard NTSC color signal to be obtained without the use of three camera tubes.

Courtesy Columbia Broadcasting System, Inc.

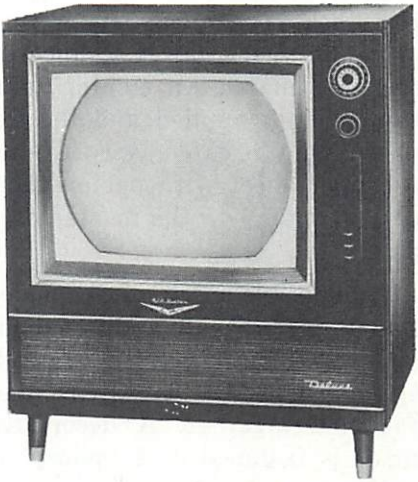
Probably the main reason for the adoption of the NTSC system was the favorable results of a series of RCA demonstrations employing a three-gun shadow mask color kinescope.

THREE-GUN PLANAR SHADOW-MASK COLOR KINESCOPE

In the **three-gun shadow-mask color kinescope,** three electron beams are used, one for each primary color. The beams bombard a phosphor screen that is composed of about 600,000 phosphor dots arranged in triangular groups or trios with one dot of each primary color contained in each of the 200,000 trios.

Located between the phosphor screen and the electron gun assembly is a thin sheet of flat perforated metal, called a **shadow-mask.** As it contains only one hole for each trio of color dots, the shadow-mask allows each beam to strike only the correct phosphor dot. That is, the electron beam which is to cause reproduction of the red portions of the picture can strike only the red-emitting phosphor dot. Likewise, the blue and green beams can strike only the blue and green dots respectively. The geometrical relation between the electron beams, the shadow-mask and the phosphor dot plate is shown in Figure 6. Due to the fact that the three guns are separated from each other physically, it is necessary to devise a means to cause the three electron beams to meet or converge at the openings in the shadow-mask. When this is accomplished, the beams are in **convergence.**

The three beams are converged at the openings in the shadow-mask by pointing the guns or by an electronic lens system similar to the methods used for focusing the beam in a monochrome picture tube. By making the angle of convergence small enough, the three electron guns can be included in one neck and a single scanning system used for all three beams.



Color television receivers have the same general outward appearance as black-and-white TV receivers. This is the RCA 21″ model "Director".

Courtesy Radio Corporation of America

As for the construction of the tube, a technique has been developed that permits fine-detail printed patterns of color phosphors to be deposited onto a flat glass surface suitable for use as the viewing screen in a color reproducer. A photo-engraving process was employed to construct the shadow-mask with a high degree of accuracy. A photographic negative is made so that an array of black dots is formed.

After having obtained a suitable master negative, a thin copper sheet is coated with engravers enamel, exposed through the negative with ultraviolet rays, and developed. The exposed enamel is insoluble but the unexposed enamel (the areas corresponding to the black dots on the master negative) is washed away to uncover the bare metal. An etching solution is then applied and the exposed metal is eaten away leaving a copper sheet with perforations corresponding to the master negative.

By suitable mechanical means, the glass face plate and the shadow-mask are correctly aligned, spaced about ½ inch apart, and fastened together. A decorative mask is fastened to the phosphor dot screen and the entire assembly, along with the electron gun assembly, is enclosed in a suitable housing.

Due to the fact that the shadow-mask and the phosphor dot screen is flat, this color picture tube has several disadvantages. Among these are focus and convergence problems arising because the electron beams must travel further when they have been deflected than they do when they are striking the phosphor dots near the center of the screen.

Another serious disadvantage of the flat shadow-mask tube is that the majority of the beam current does not strike the phosphor dots but is collected by the shadow-mask. This results in only about 15% of the total beam current exciting the phosphors to produce light. The remaining 85% does nothing but heat up the shadow-mask and cause it to expand. This makes it necessary for the shadow-mask to be stretched tightly before being placed in position so that the expansion due to heat does not cause a misregistry of the holes in respect to the center of the dots on the phosphor dot plate.

CBS-COLORTRON

Using the flat shadow-mask color picture tube as a basis for study, CBS-Hytron undertook the development of a shadow-mask tube that could be manufactured at a reduced cost and could be made comparable to the larger black and white kinescopes.

The first step was to develop a process that would enable the phosphors to be printed on the curved internal surface of the tube. This development then would permit the construction of a self-supporting curved shadow-mask that would be light enough to mount it directly on the face plate. However, before going into the constructional features of the colortron, we want to analyze some advantages of this type of construction.

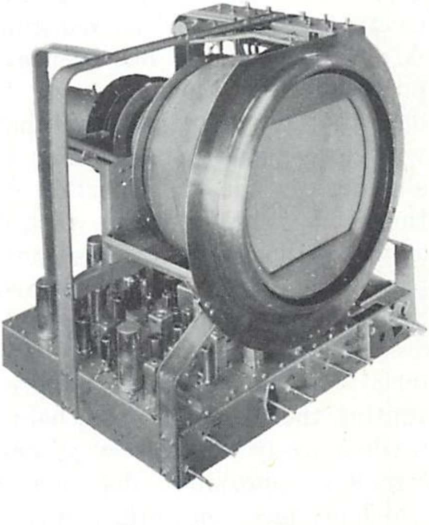
In the planar shadow-mask picture tube, it is necessary to apply variable focusing and convergence voltages to compensate for the different distances of beam travel as the raster is scanned. These are called dynamic focus and dynamic convergence voltages and are added to a steady state voltage on the focus and convergence electrodes.

In the **colortron** tube, the picture is formed on the curved face and a matching curved shadow-mask is used. Figures 7 and 8 show that a curved shadow-mask affords ideal conditions for focus and convergence respectively at all points on the screen. As shown, both the focus and the convergence are better for a curved face plate than for a flat one. On a plane perpendicular to the tube axis, the electron beam(s) would "spread". Unless a correction is applied, the error in convergence is very great for a planar shadow-mask tube but is considerably reduced for the curved mask tube. Not only is the correct convergence more easily obtained in a curved mask tube but in the event of improper adjustment of the dynamic convergence system, the convergence error is many times less than it would be for a flat shadow-mask tube.

Construction and Processing

A technique which is simple, accurate and suitable for mass production is used for depositing the phosphors on the curved face plate.

The screen is initiated in each step by settling one of the three color phosphors over the entire screen from a liquid solution. After the phosphor has settled, the liquid is drained and a suitable photosensitive material is used to coat the phosphor. This surface is then exposed to a light source through the openings in the



The color TV receiver pictured here employs one of the early 15" picture tubes. Notice the compact design of the complete receiver.
Courtesy Admiral Corporation

curved shadow-mask that is to be used for that particular tube. In this way the shadow-mask serves as a negative to make its own image on the phosphor. Since no master negative is used, there is no need for all shadow masks to be identical.

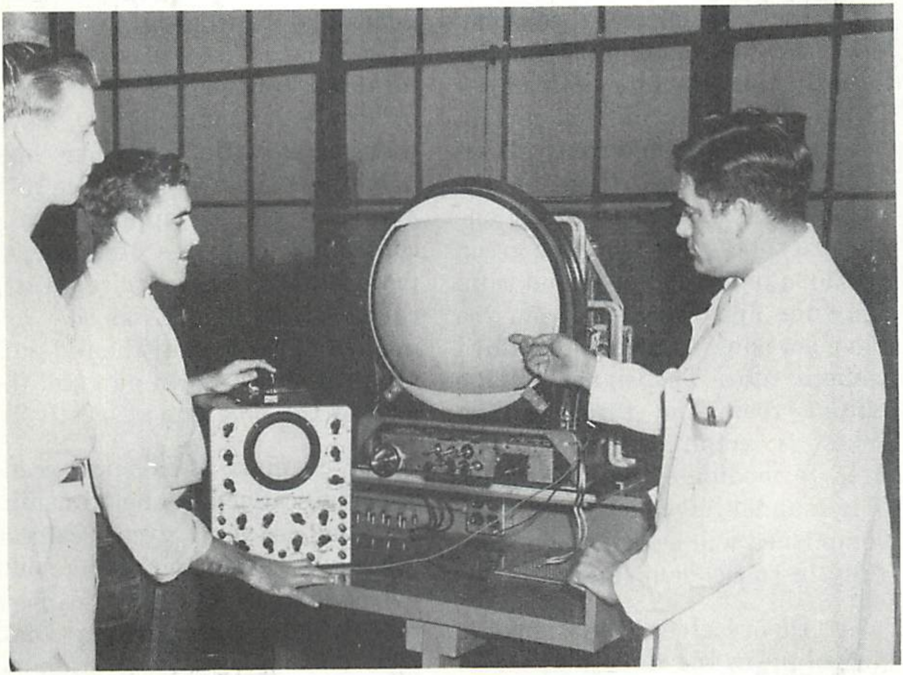
In the photographic exposure process, the light source is placed in a position that simulates the size and position of the electron beam in the finished tube. For example, if the red phosphor is applied first, the light source is placed so that it simulates the electron beam from the red gun. After the phosphor has been exposed, a development process is used that allows the material that was not exposed (that which is shielded by the solid portion of the shadow-mask) to be washed away. At those points on the phosphor where the light passed through the openings in the shadow-mask, the photo sensitive material has the property of preventing the phosphor from being washed away. In this way, one complete phosphor dot array which produces one of the primary colors is placed on the screen.

Now, the shadow-mask is constructed so that it can be inserted or removed from the front face plate in a few seconds. This is important because it is necessary that four insertions and three removals be accomplished before the tube is completed. To prevent any misregistration of the phosphors due to these insertions and removals, physical alignment points are built in as part of the shadow mask and the glass face plate. These consist of a glass hemisphere and a "V" groove which are aligned on each insertion. Figure 9 illustrates the physical arrangement of the entire tube assembly.

After depositing another layer of different color phosphor (blue for example), over the entire screen, the shadow-mask or aperture mask, is reinserted in exactly the same position and the light source is relocated to simulate the electron beam from the gun corresponding to the phosphor being deposited. The entire photographic process of exposure, removing the mask, and washing away the unexposed phosphor is repeated. This enables the second phosphor dot array to be deposited and the entire procedure is repeated for the third array of phosphor dots. The total number of dots is about 600,000 which is the same number as in the flat shadow-mask tube.

To increase the brightness of the picture and to maintain a constant screen voltage for the operation of the tube, the entire screen is aluminized.

A triangular gun arrangement is employed and various methods have been used successfully for aligning the three guns with the openings in the shadow mask. Also, the tube may be re-gunned, if necessary, without damage to the screen or to the mask. This is an important consideration to both the manufacturer and the user as it enables a good percentage of the tubes to be repaired at considerably less cost than the price of a new tube.



The Motorola color TV receiver pictured here employs the 19″ Colortron picture tube. The instructor is demonstrating the use of the scope in observing the various wave-forms encountered.

DTI Photo

Although further experimental work is in process, practically all of the color picture tubes in use are those which have the phosphor dots deposited on the inner surface of the glass face plate. These are being made by several manufacturers in sizes varying from 19″ to 24″ in diameter.

USING THE THREE-GUN SHADOW-MASK TUBE

Due to the convergence problems and the small percentage of total beam current that is used to activate the phosphors on a shadow-mask color picture tube, many experiments are at present being conducted to find ways and means of developing a tube to eliminate the convergence problem and to utilize more of the beam current. In fact, several such tubes have already been constructed on an experimental basis. However, before considering these tubes and their possibilities, an idea of the manner in which the three-gun shadow-mask tube is employed will be helpful so that the problems encountered by the experimenters will be better understood.

At the transmitter, three camera tubes are employed simultaneously and a primary color filter is placed in front of each camera tube. This arrangement allows light from red portions of the scene being viewed to affect one camera tube, light from the green portions to affect the second camera tube and the light from the blue portions to affect the third camera tube. The signal voltage output from the three camera tubes is amplified, mixed, and used to modulate the r-f carrier. The manner in which this is accomplished will be explained more fully in subsequent lessons.

At the receiver, the signal is picked up in the same manner as a monochrome signal, passed through the tuner, the video i-f amplifiers and detected by the video second detector. From the video second detector the signal is divided into the luminance signal and the color or chrominance signal. In a regular black and white TV receiver the luminance signal is used to produce the picture and the chrominance signal is not used which accounts for the compatibility of the present color TV transmission system.

In a color TV receiver, the luminance signal is amplified to the proper level and is fed to a matrix system. The chrominance signal is fed to a special chrominance amplifier and then to the color demodulators where it is converted to what is known as the color-minus-brightness signals. The brightness or luminance signal is then mixed with the color-minus-brightness signals to produce voltages that can be applied to the controlling elements of the color picture tube. These voltages are called E_R, E_G, and E_B as they are applied to the grid of the red gun, the grid of the green gun and the grid of the blue gun respectively.

For example, if a yellow scene is being scanned at the transmitter, the red and green camera tubes will have equal voltage outputs whereas the blue camera tube will have zero voltage output. This follows from explanations in a previous lesson that the addition of red and green light result in yellow light. These voltages then undergo desired actions in the transmitter and the receiver circuits so that they reappear as pulses of voltage that can be applied to the grids of the red and green guns of the color picture tube. In this example, only the red and green phosphors on the face of the CRT are excited. This simultaneous excitation of the red and green phosphors is interpreted by the human eye as yellow light.

In order to produce the correct hue with equal voltages applied to the grids of the red and green guns, it is necessary that the amount of light given off by the red and green phosphors be equal. Unfortunately, the red phosphor is only about 50% as efficient as the green phosphor. This means that if equal signal voltages are applied to the grids of the red and green guns, the green phosphor will give off about twice as much light as the red phosphor and the human eye would interpret this as a greenish-yellow hue rather than the yellow it is supposed to be.

This difference in the efficiencies of the phosphors is partly compensated by applying the red and green signal voltages to separate amplifiers and adjusting their gain so that the red signal voltage (E_R) is amplified about twice as much as the green signal voltage (E_G). It also is necessary that the d-c operating voltages applied to the screen grids and the bias voltage between the control grids and cathodes be properly adjusted. In practice it will be found that the red gun screen voltage is higher than the green screen voltage and the bias applied to the red gun is less than the bias applied to the green gun.

Up to this point, no mention has been made of the blue gun since it is assumed that a yellow portion of the scene is being transmitted and yellow does not contain blue light. However, when a portion of the scene being scanned does contain blue light, the blue amplifier and the blue gun must also be functioning properly. The efficiency rating of the blue phosphor is very similar to that of the green phosphor and it is found that operating conditions for the blue amplifier and the blue gun are very much the same as for the green amplifier and the green gun.

Even though the circuits used to compensate for the varying efficiencies of the phosphors appear to be complex, they actually are fairly simple to design, construct and maintain. The requirements are that a separate video amplifier (just like the video amplifier in a regular black and white TV receiver) be employed for each of the three primary color signals with a means provided for adjusting their respective gains. Also, separate bias and screen grid controls must be provided. This requirement entails quite a few controls which are pre-set at the factory or by the TV serviceman. Most of these controls can be adjusted by observing the face of the color picture tube and without the aid of any test equipment (a detailed explanation of these adjustments is given in another lesson).

The idea behind this general explanation is to bring out the fact that the circuitry used to control the conduction of the three guns is simple even though there are a considerable number of components. The importance of this simplicity of circuit design and adjustment will be better understood when other types of color picture tubes are analyzed.

The 21AXP22 is one of the latest 21" picture tubes developed and currently being used extensively. It has the phosphor dots printed directly on the inside of the glass face plate.
Courtesy Radio Corporation of America

The remaining important factor of the three-gun shadow-mask picture tube is the matter of convergence and purity. In the present-day shadow-mask CRT's, the three guns are housed in a single neck being geometrically placed to form an equilateral triangle so that only one deflection yoke is required. The guns are aimed and the external voltages and currents are adjusted so that the three beams meet or converge at the openings in the shadow-mask as shown in Figure 6. As they pass through the openings in the shadow-mask, the three beams diverge slightly and strike the correct phosphor dot.

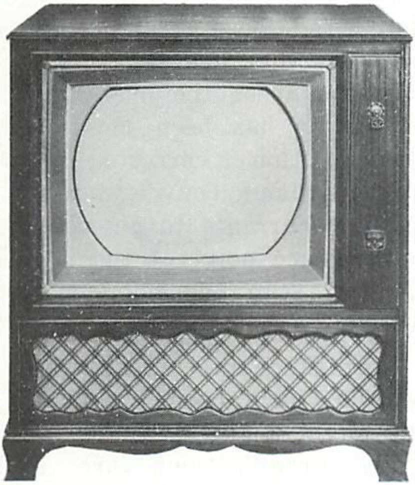
In the actual construction of the picture tube, it is virtually impossible to place the guns in an exact equilateral triangle. Therefore, external magnets are used to individually position the three beams so that they do form an equilateral triangle even though the guns do not. Another magnetic field is then used to align all three beams so that they strike the proper phosphor dots. Similar to a focus coil around the neck of the CRT, this alignment is accomplished by varying the current through the coil and physically adjusting its position. The coil is called the PURITY COIL as it causes the red beam to strike only red dots and produce a pure red color, the green beam to strike only green dots and produce a pure green color, and the blue beam to strike only the blue dots producing a pure blue color.

These convergence and purity adjustments are made while examing a small, centrally located area on the face of the color picture tube. Neglecting the effect of any external magnetic fields, the three beams continue to strike the proper color dots when the beams are deflected away from the center of the CRT; that is, the red beam strikes red dots, the green beam strikes green dots and the blue beam strikes blue dots. This is due to the angle at which the electron beams enter the holes in the shadow-mask. In actual practice, the earth's magnetic field has a tendency to affect the angle at which the beams enter the openings in the shadow-mask and cause the beams to strike the wrong color phosphor dots. This condition is corrected by placing a coil or small permanent magnets around the front of the CRT. The current through the coil or the magnetic field of the permanent magnets is then adjusted to counteract the effect of the earth's magnetic field so that the beams produce pure colors.

Referring back to Figure 8, notice that the distance the three beams must travel, when they are deflected to the edges of the phosphor dot screen, is greater than the center distance and the three beams will converge too soon. This condition is known as over-convergence and the results are more clearly illustrated in Figure 10. Here, the trio of dots labeled G_1, R_1, and B_1 are those that would have been struck if the three beams were properly converged. Due to the over-convergence condition, the green beam will enter the shadow-mask opening to the left of the proper opening and strike the dot labeled G_3; the red beam will enter the opening to the right and strike the dot labeled R_2; the blue beam will enter the opening below the proper point and strike the dot labeled B_4. Assuming that the three beams were supposed to produce one white dot, they will now produce a red dot, a green dot and a blue dot that are separated by the amount of the over-convergence. As has been mentioned, this condition is corrected by applying dynamic convergence voltages or currents to change the convergence point of the beams as they scan the phophor dot screen.

Since all of these difficulties appear to have been ironed out, one might begin to wonder why many organizations are still spending much time, effort and money in an attempt to produce a different type of color picture tube. Further, it should be mentioned that, at this state of development, the three-gun shadow-mask picture tube with the phosphor dots deposited directly on the glass face plate is the only color picture tube that is being mass produced on a production line basis. In fact, the large manufacturers of this picture tube are expanding their production facilities in anticipation of widespread public acceptance and probable purchase of the color TV receiver in the present state of the art.

As good as the three-gun shadow-mask color picture tube is, it has some disadvantages that, if they can be overcome, would reduce the cost of the picture tube and its associated circuits and proportionately reduce the cost of a color TV receiver. Naturally, the manufacturers are always looking for a way to produce a good quality receiver as economically as possible.



Another example of the beautiful styling obtainable in the modern 21″ color television receivers. The operating controls are located behind the closed panel on the right.

Courtesy Allen B. DuMont Laboratories, Inc.

One of the major disadvantages of the three-gun shadow-mask tube is its poor efficiency rating in using the total beam current of the three-guns. As previously mentioned, the solid portion of the shadow-mask covers considerably more area than does the openings. This is necessary to prevent the beams from striking the wrong dots during the scanning period. As a result only about 15% of the total beam current is utilized in producing light while the remainder is collected by the shadow-mask. Consequently, it becomes necessary that each beam be capable of supplying about 200 microamperes in comparison to about 60 microamperes for the average beam current in a monochrome picture tube. Along with this total of 600 microamperes, the high voltage supply must furnish about 25,000 volts—for a 19″ or 21″ tube—and the brightness is still lower than that of a comparable size monochrome picture tube. This large beam current and the high voltage required present additional problems in the design of high voltage power supply.

If the flyback high voltage system is designed to produce a pulse that has a peak amplitude of 25,000 volts, the construction of the horizontal output transformer becomes subject to arc-over and breakdowns. Besides this, the placement of leads and the soldered connections become very critical in order to prevent corona discharge—especially during damp weather. Also, the rectifier tube must be of a type to withstand high pulse voltages. To eliminate some of these problems, voltage doublers are practically always employed in the high voltage system.

Another disadvantage of using such a large high voltage is the reduction in the deflection sensitivity. As explained in an earlier lesson, when the high voltage is increased, the electron travel from the cathode to the phosphor screen is speeded up and the beams are more difficult to deflect. Because of the reduction in deflection sensitivity, more power must be supplied to the deflection coils. As a result of the increased power requirements, the components used in the scanning circuits must be more sturdily constructed which adds to manufacturing costs.

Besides all this, the large beam current presents another serious high voltage problem. Since the total beam current of the three guns can vary from zero at cutoff to a maximum of about 600 microamperes, the high voltage supply must be capable of delivering this varying current with very little change in the high voltage. Any serious change in the high voltage can cause the size of the raster to change, the beams to go out of focus and out of convergence. Due to the inherent poor regulating characteristics of a voltage doubler system, some method of regulating the high voltage must be used.

Last, but by no means least, of the disadvantages of the three-gun shadow-mask color picture tube is the danger of physical contact with a high voltage supply that is capable of delivering the amount of power required by this color picture tube. In the high voltage supply for a monochrome picture tube, the total value of capacitance used for filtering purposes is about 500 to 1000 $\mu\mu$f and the shock that can be obtained by contact is not especially dangerous even though such a capacitor is charged to a voltage of 10,000 to 16,000 volts. In the high voltage supplies for the color picture tube, capacitors as large as 5,000 $\mu\mu$f are used for the filter capacitors. Combined with the 25,000 volts to which they are charged, this means that they are capable of supplying about 10 times the amount of power to a person unfortunate enough to come in contact with them. Thus, such a power supply constitutes a rather dangerous shock hazard.

Now that the operating conditions of the three-gun shadow-mask picture tube have been explained, let us investigate what is being done by the experimenters and manufacturers to develop a color picture tube that is more efficient and which will produce a good quality color picture.

THE LAWRENCE TUBE

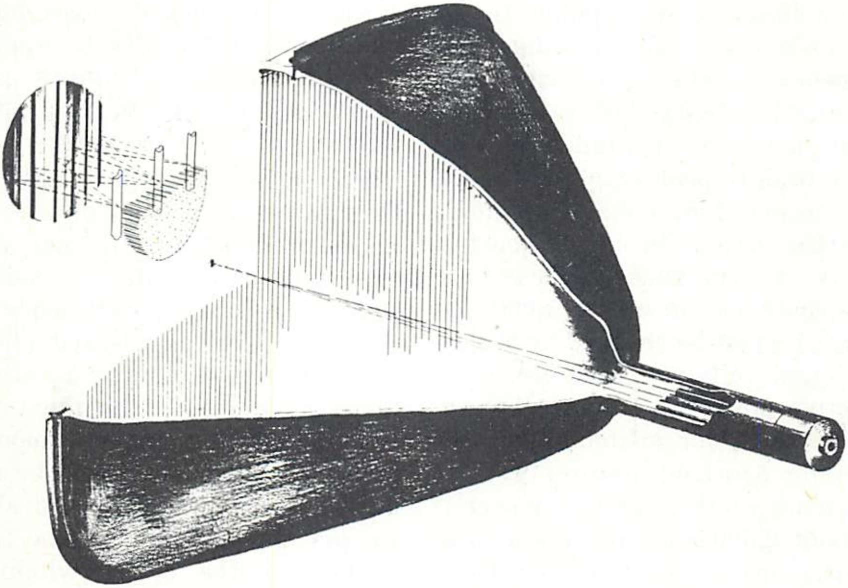
One of the most promising of the experimental color picture tubes is one which employs a series of vertical color strips. Designed by professor E. O. Lawrence of the Chromatic Television Laboratories, it is commonly called the Lawrence tube. Due to the fact that it is relatively easy to construct, extensive experiments are being conducted in an effort to make it practical.

The viewing screen is a flat glass plate upon which are deposited about 400 green phosphor strips and about 200 each of red and blue phosphor strips as illustrated in Figure 11. Located about 0.4 of an inch closer to the gun is a grid structure of 400 vertical wires with every other vertical wire being connected electrically together. When viewed from the gun end of the picture tube, the red grid wires are in alignment with the centers of the red phosphor strips and the blue grid wires are in alignment with the centers of the blue phosphor strips.

The vertical grid wires are 8 mils in diameter and the spacing from center to center is 40 mils. The spacing between the wires covers a green phosphor strip and half of the adjacent red and blue phosphor strips. The spacing between the center of a blue strip and the center of a red strip is 40.6 mils which is .6 mil greater than the spacing between the centers of adjacent grid wires. This arrangement results in the phosphor strips being displaced outwardly from the corresponding grid wire as they progress towards the edges of the screen, compensating for the variation in the angle of deflection of the electron beam as it scans the screen. In operation, the grid structure is about 4000 volts positive in respect to the cathode to lower the amount of deflection power required and to permit the electron beam to be sharply focused. The phosphor screen is then operated about 16,000 volts positive in respect to the cathode to provide the remainder of the accelerating voltage after deflection of the beam has occurred. The actual values of these voltages are not critical but the ratio is. For best focusing results, the phosphor screen potential should be four times as great as the grid structure potential.

As mentioned, the wires in the grid structure are alternately connected together and each group has applied to it the proper color switching signal voltage besides the 4,000 volts. When no signal voltage is applied between the sets of grid wires, the electron beam passes through them undeflected and hits the green phosphor strips. In order for the electron beam to hit the red phosphor strips, a color switching voltage is applied so that the red grid wires are positive and the blue grid wires are negative. Assuming this to be the case, the electron beam of Figure 11 would be attracted by the positive red grid wire at its left and repelled by the negative blue grid wire at its right causing the beam to deflect to the left and strike the red phosphor strip.

When the scanning action moves the beam over one space to the left, the negative blue grid wire will repel the electron beam slightly to the right and the positive red grid wire will attract it to the right once again causing the beam to strike the red phosphor strip. The peak amplitude of



Artist's sketch of the "post acceleration" color picture tube in development at General Electric's cathode ray tube sub-department in Syracuse.

Courtesy General Electric

the color switching voltage is approximately 440 volts. However, to change from red light to blue light, the polarity of the signal must reverse so that the total color switching voltage must have a peak to peak amplitude of about 880 volts.

Since the present day NTSC system of color TV transmission is a simultaneous one, it is necessary that the frequency of color switching voltage, applied to the grid wires, have the same frequency as the color subcarrier which is 3.58 mc. This rather high frequency, in conjunction with the peak to peak amplitude of the color switching voltage, created a rather serious problem. The two sets of grid wires form a total capacitance of about 1,000 $\mu\mu$f which must be charged by the deflection voltage. Therefore, a reactive power is necessary to enable the color switching voltage to be applied properly. The amount of this reactive power is about 2,500 volt-amperes and, at the moment, is one of the major reasons why the single gun, three color Lawrence tube is still in the experimental stages.

Another factor that must be considered in the operation of the Lawrence tube, is the manner in which the conduction of the beam is to be controlled. From the explanation concerning the three-gun shadow-mask color picture tube, it should be remembered that the conduction of each of the three guns had to be controlled simultaneously in order to reproduce the proper colors. The fact that the conduction of any single-gun tri-color picture cannot be controlled simultaneously necessitates the use of some circuit arrangements quite different than those used in a three-gun color picture tube.

Furthermore, the difference in efficiencies of the three phosphors had to be compensated by applying different bias voltages and screen grid voltages to the proper elements of the three guns.

It is possible to compensate for the relative inefficiency of the red phosphor by mixing the blue and green phosphors with a material that will reduce their efficiency to the same level as the red phosphor. Of course, this is a rather undesirable method as the total light output for a given amount of total beam current will be reduced. It is much more desirable to vary the bias at the same frequency as the color switching voltage and reduce the conduction of the beam as it strikes the blue and green phosphors.

Finally, the received chrominance signal containing the video information which determines the hue and saturation of the color to be reproduced must be converted to color-minus-brightness signals and mixed with the *luminance* signal to obtain the proper signal voltages for application to the conduction controlling element of the picture tube. Without going into details, this requires the red video signal to be applied to the grid while the beam is striking the red phosphors dots, the blue video signal to be applied to the same grid while the beam is striking the blue phosphor dots and likewise for the green portion of the video signal. The circuitry necessary for this type of a system is rather complicated but can be designed to operate satisfactorily.

Summing up the features of the Lawrence tube, its greatest drawback is the large amount of reactive power required to perform the color switching at the grid wires. In an effort to overcome this obstacle, attempts are now being made to reduce the size of the grid wires, increase the number of wires and reduce the spacing between the wires in the hopes that the amount of reactive power necessary for color deflection can be reduced to a practical level.

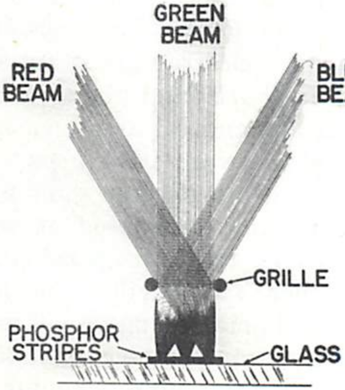
In its favor are the increased brightness that can be obtained, as the biggest percentage of the beam current is converted to light, and the reduced requirements of the high voltage supply.

THE GE POST-ACCELERATION TUBE

Following along somewhat similar lines as the Lawrence tube is a new picture tube being developed by the General Electric Company which is referred to as a **post-acceleration tube.** As the term implies, the electron beams are accelerated after they have been deflected. The tube utilizes some of the principles of the Lawrence tube and some of the three-gun shadow-mask tube. A general idea of the physical construction of the post-acceleration tube can be obtained from the sketch of Figure 12.

The phosphor screen is constructed of vertical strips of three phosphors which emit light of the primary colors when energized by the electron beams. This tube employs three electron guns that are all in one horizontal plane rather than in a triangular arrangement. Located between the phosphor screen and the electron guns is a grille network composed of vertical wires that are parallel to each other. These grille wires are very small, measuring only 3 mils in diameter and spaced about 35.7 mils from the center to center to provide 28 wires per inch. Since this tube measures about 20 inches across its face, a total of approximately 560 wires is used. Also, there is one each of the primary color phosphors for each grille wire so that there are approximately 560 red strips, 560 blue strips, and 560 green strips.

Although no definite information has been obtained as to the distance from the phosphor screen to the grille wires, it is likely that this distance is approximately one inch. Naturally, the actual design distance will be determined by the results of many experiments. In this tube, the grille is the color selecting electrode and it is constructed so that about 90 per cent of the total beam current of the three guns strikes the phosphor screen to produce light. In comparison with the 15% efficiency of the shadow-mask color picture tube, this is an enormous increase in overall brightness.



Electron beams enter grille of General Electric's developmental "post acceleration" color picture tube with an angular separation of less than one degree. This is greatly exaggerated in the above sketch.

Courtesy General Electric

In operation, the grille wires are all connected together and are approximately 6,300 volts positive in respect to the cathodes of the three guns. The phosphor screen is held about 25,000 volts positive in respect to the cathodes. As in the Lawrence tube, the three beams are accelerated after they have been deflected by the scanning circuits which means that about one-half of the usual deflection power is required.

When the electron beams enter the space between the grille wires, they are bent towards the phosphor screen as shown in Figure 13 which is a top view of the action taking place inside the tube. At this point it might be well to mention that the bending action illustrated in Figure 13 is greatly exaggerated since the actual angle of bend is about one degree. This bending action is caused by the large difference in potential between the grille wires and the phosphor screen (about 18,700 volts). When the electrons are emitted by the cathodes, they are accelerated only by the 6,300 volts d-c applied to the grille and approach it at a relatively slow speed. As the electron beams enter the region of the grille, they are immediately attracted by the high positive voltage of the phosphor screen and are accelerated toward it with high velocity.

Besides being bent toward the phosphor screen, the electron beams are sharply focused in the horizontal dimension so that the width of each beam is considerably smaller than the width of the phosphor strip. As a result, color purity is quite easily obtained as the narrow beam can be moved about slightly by control adjustments without the beam hitting a wrong strip. Increased allowances in the mechanical and electrical tolerances are permitted.

The grille network does not have the ability to focus the beams in the vertical dimension so it is necessary to design a gun that will produce an adequately focused beam before it reaches the grille.

Figure 14 illustrates the paths that the beams can follow between the grille and the phosphor screen depending upon the ratio of the screen voltage to the grille voltage. Path A is that which would be followed if the voltages were equal; path B is when the phosphor screen voltage is higher than the grille voltage; and path C is when the phosphor screen voltage is made still higher than the grille voltage. The amount of bending is directly proportional to the ratio of the screen voltage to the grille voltage and it is necessary that this ratio be kept constant when the tube is in operation. It has been found that the two voltages must be regulated to within 5 per cent of the ratio for which the tube is designed.

The problem of convergence still exists in the post-acceleration color picture tube because three guns are employed. Experiments have shown that the single plane construction of the three guns simplifies the convergence of the three beams and fewer controls are necessary.

Since it has been pointed out that the post-acceleration tube has considerably more brightness than the shadow-mask tube, it should also be mentioned that the contrast for the p-a (post acceleration) tube is less. Secondary electrons which strike the phosphor screen in a random manner in the p-a tube cause the excitation of a white background. By sacrificing some of the brightness through the use of a high attenuation safety glass, the contrast is improved but is still slightly less than that of the shadow-mask tube. When viewed in a room that has a considerable amount of illumination, however, the increased brightness of the post-acceleration tube enables the picture to be seen very easily and with a higher contrast ratio than a picture viewed on the shadow-mask tube.

Taking all things into consideration, it appears as though the possibilities of the post-acceleration tube will enable it to be used successfully with our present day system of color transmission. It is difficult to predict when the tube will be put into production.

Since the color television industry is very young, it can be expected that a large number of changes will take place in the manufacture of many of the components that are now being used and that new circuitry and design will reduce the number of tubes and components required.

In any event, the system of transmission has been selected by the FCC and regardless of changes made in components and circuitry, the overall functions of color TV receivers will remain the same. Accordingly, the following lessons explain the details concerning the NTSC system of transmission and the circuits that will be found in a present day color TV receiver.

IMPORTANT DEFINITIONS

COLOR SWITCHING—The application of a suitable voltage to a control element in a color picture tube to allow an electron beam to strike the proper color phosphor.

COLORTRON—A three-gun shadow-mask tube designed by CBS-Hytron in which the phosphor dots are deposited directly on the inner curved surface of the face of the CRT. The shadow-mask is then curved proportionately.

COMPATIBLE COLOR SYSTEM—Any method of color television transmission that will permit monochrome TV receivers to reproduce a color telecast in black and white without any changes in the receiver. The present NTSC system fulfills these requirements.

CONVERGENCE—In a three-gun shadow-mask color picture tube, the bringing together of the three electron beams so that they meet at the openings in the shadow-mask. This is accomplished by pointing the three guns at a slight angle towards each other and by employing either an electric or a magnetic field through which the three electron beams must pass.

FIELD SEQUENTIAL TRANSMISSION—A method of color television transmission in which video information for one primary color is sent for one complete VERTICAL scanning period. The second primary color information is sent during the next vertical scanning period and the third primary color information sent during the third vertical scanning period. The sequence is then repeated.

LINE SEQUENTIAL TRANSMISSION—A method of color television transmission in which video information for one primary color is sent for one complete horizontal scanning line. The remaining two primary colors are then transmitted during the next two successive horizontal scanning lines. The sequence is then repeated.

IMPORTANT DEFINITIONS—(Continued)

POST-ACCELERATION TUBE—A color picture tube which employs vertical strips of color phosphors, a network of vertical wires called a grille and three electron guns. The tube derives its name from the fact that acceleration of the electron beams occurs after they have been deflected.

SHADOW-MASK—A thin perforated sheet of metal that is either flat or curved depending upon the picture tube in which it is being used.

SIMULTANEOUS TRANSMISSION—A method of color television transmission in which information concerning all three primary colors is sent at the same instant of time. The NTSC method now being used is a simultaneous system of transmission.

THREE-GUN PLANAR SHADOW-MASK TUBE—A tube designed specifically for color television receivers in which three primary color phosphors are deposited on a flat glass plate in groups of three dots (one for each color). A flat mask with an opening for each trio of dots permits the electron beam from each of three-guns to strike the proper color dot.

STUDENT NOTES

STUDENT NOTES

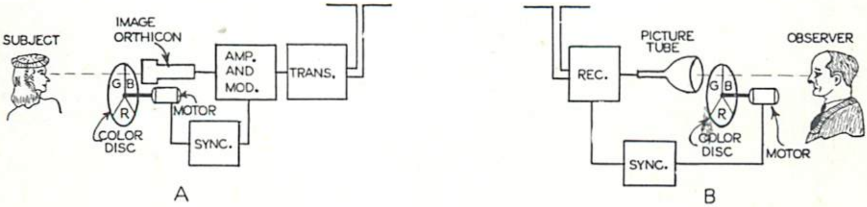


FIGURE 1

SCANNING PERIOD	FIELD	FRAME		COLOR FRAME			COLOR PICTURE					
TIME INTERVAL IN SECONDS	$\frac{1}{144}$	$\frac{1}{72}$		$\frac{1}{48}$			$\frac{1}{24}$					
LINES SCANNED	EVEN	ODD	EVEN	ODD	EVEN	ODD	EVEN	ODD	EVEN	ODD	EVEN	ODD
COLOR OF FILTER	R	B	G	R	B	G	R	B	G	R	B	G

FIGURE 2

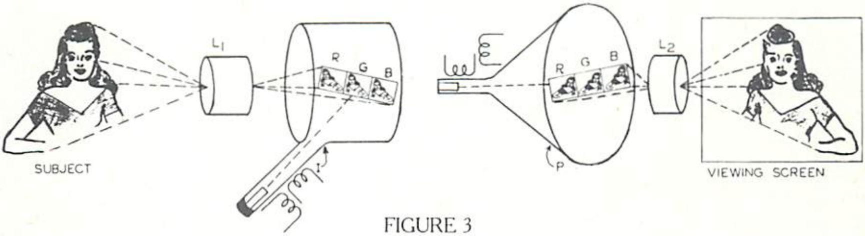


FIGURE 3

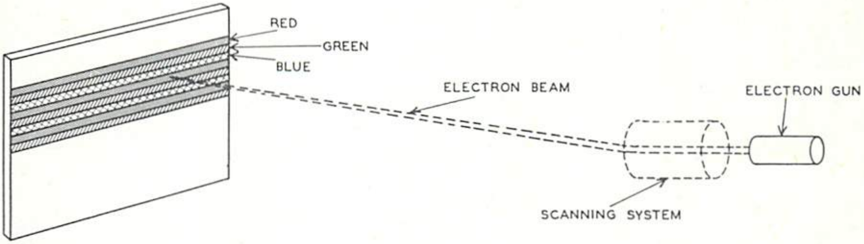


FIGURE 4

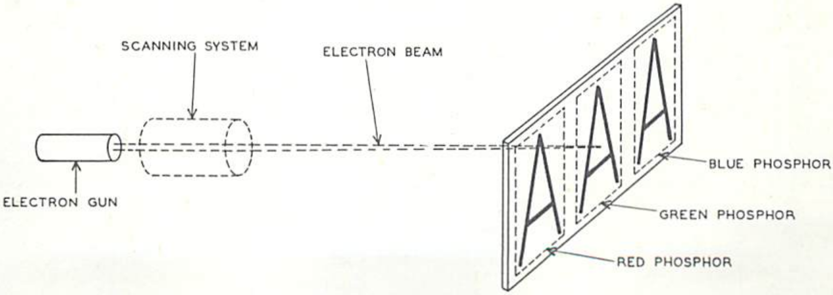


FIGURE 5

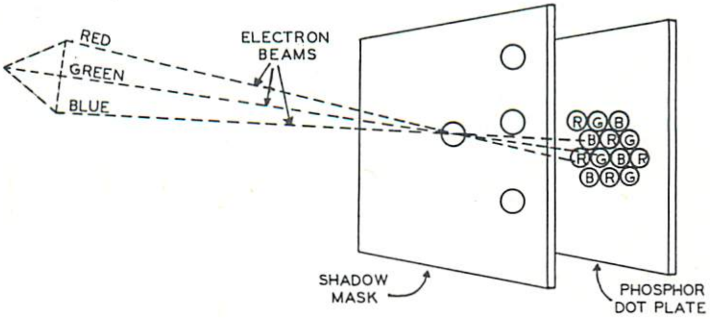


FIGURE 6

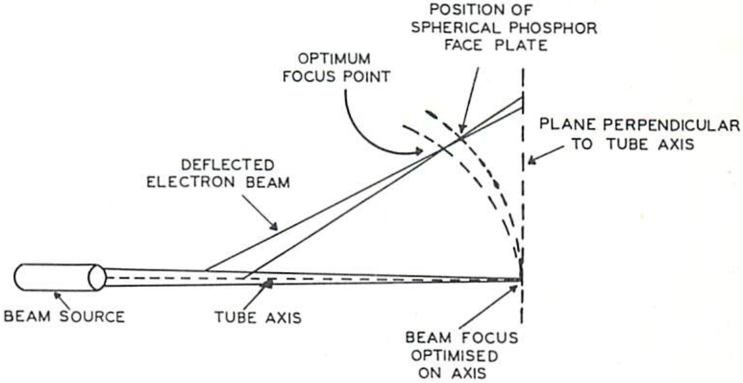

POSITION OF SPHERICAL PHOSPHOR FACE PLATE
OPTIMUM FOCUS POINT
PLANE PERPENDICULAR TO TUBE AXIS
DEFLECTED ELECTRON BEAM
BEAM SOURCE
TUBE AXIS
BEAM FOCUS OPTIMISED ON AXIS

FIGURE 7

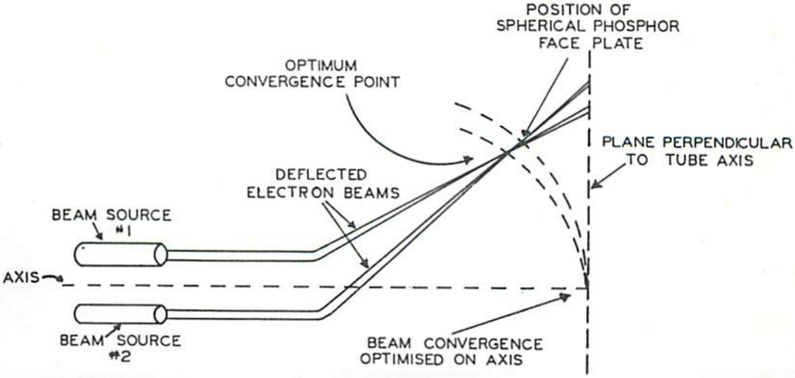

POSITION OF SPHERICAL PHOSPHOR FACE PLATE
OPTIMUM CONVERGENCE POINT
PLANE PERPENDICULAR TO TUBE AXIS
DEFLECTED ELECTRON BEAMS
BEAM SOURCE #1
AXIS
BEAM SOURCE #2
BEAM CONVERGENCE OPTIMISED ON AXIS

FIGURE 8

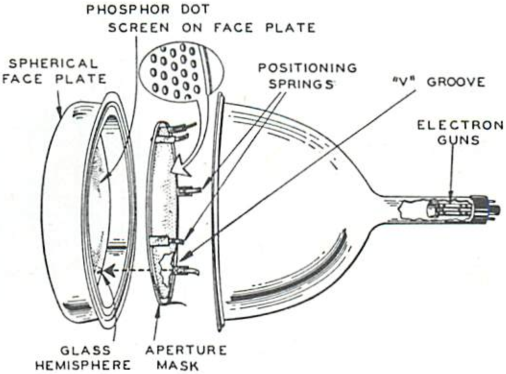


FIGURE 9

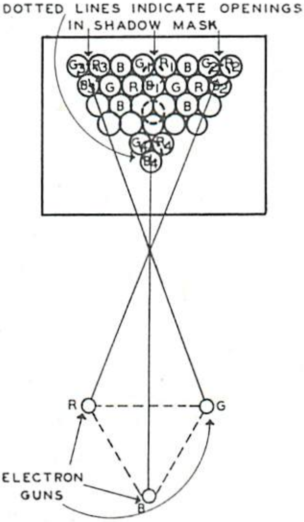


FIGURE 10

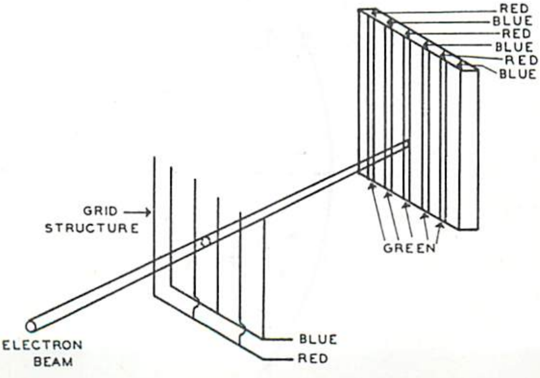


FIGURE 11

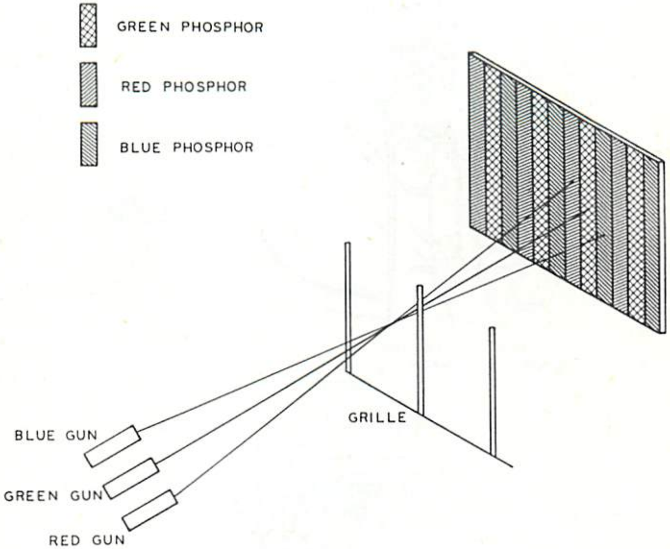


FIGURE 12

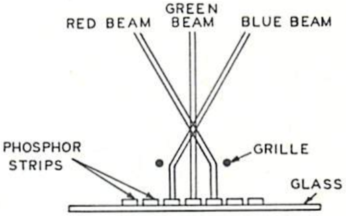


FIGURE 13

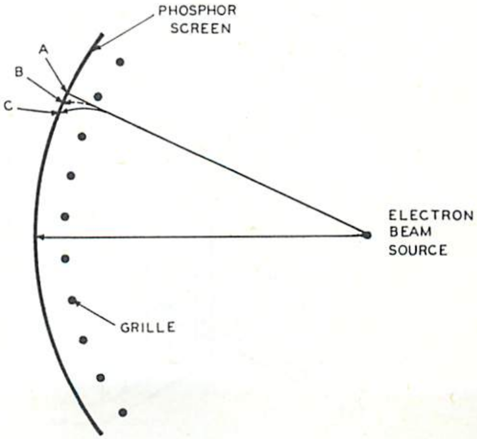


FIGURE 14

FROM OUR *Director's* NOTEBOOK

THE CUSTOMER'S IMPRESSION OF YOU

The fellow who pays the bill, the customer, is a mighty important man in your life when you have your own service shop. He's your reason for being in business; he's the fellow who keeps you in business.

The impression you make on your "meal ticket" is important, right from your first contact with him to the present time. Your own personal appearance and that of your shop . . . the way you answer the phone . . . the way you go about your service work, especially in the customer's home . . . your method of handling customers, whether they be complaining or merely inquiring . . . in fact, everything about your business operations—these are all important to the customer.

When you are determined to give your customer your best efforts, you're bound to give the impression of being a good, solid businessman. That's what keeps your customers coming back. And that's what a lasting business is built on.

Yours for success,

W. C. DeVry

DIRECTOR

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